"Referring to Figures 3-5, Kasner discloses a method for laser machining a depthwise self limiting blind via (18) in a multilayer target (10) including first (11) and second (23) conductor layers and a dielectric layer (26) having respective ablation energy thresholds as claimed including generating a first laser output (57) containing at least one laser pulse having a first energy density over a first spatial spot size, the first energy density being greater than the first conductor ablation energy threshold (col. 6, lines 50-55), applying the first laser output to the target to remove the first conductor layer within a first spot area of the target (col. 8, lines 18-20), generating a second layer [laser] output (56) containing at least one laser pulse having a second energy density over a second spatial spot size, the second energy density being less than the first and second conductor ablation thresholds (col. 7, lines 39-41) and greater than the dielectric ablation energy threshold (col. 6, lines 35-40), and applying the second laser output to the target to remove the dielectric layer within a second spot area of the target (col. 8, lines 25-30), leaving the second conductor layer unvaporized and forming a depthwise self-limiting blind via.

"The dielectric material is glass-reinforced epoxy, for example (col. 5, lines 10-30) and the conductor layers are copper (col. 4, line 65). Some of the laser pulses have wavelengths of 400 nm (col. 6, line 57). The first spatial spot size is about 38 microns (col. 7, line 66). Some of the laser outputs are generated by a solid-state Nd:YAG laser (col. 8, line 17). The target is a circuit board (col. 4, line 63.)"

Applicants respond to this rejection as follows.

Applicants have amended claim 1 to recite that the first and second laser outputs have wavelengths of less than 400 nm. Kasner et al. employ two different wavelengths to form blind vias. The first wavelength, from 0.4 to 3 microns (see column 6, line 57) and preferably 1.06 microns from a pulsed Nd:YAG, is employed to drill through metal or nonmetal material. The second wavelength, from 8 to 15 microns and preferably from 10.6 microns from a pulsed CO_2 laser, is employed to drill through nonmetal material. The second wavelength is selected because it is highly reflective to the metal layer. Kasner et al. employ signal detection circuitry to detect the reflected light from the metal layer and stop the laser drilling in response to the detected light to form a blind via. Thus, Kasner et al. relies on the reflection properties of different materials at different wavelengths.

Kasner et al. neither teach nor suggest the use of laser wavelengths below 400 nm. In fact, at wavelengths below 400 nm, there

would be minimal reflected energy, so the method of Kasner et al. would not be likely to work. In contradistinction, claim 1 relies on the relative ablation thresholds of materials at wavelengths below 400 nm. The physics between the Kasner et al. methodology and the methodology of the present invention is different.

Claim 3 is cancelled because certain of its subject matter has been incorporated into claim 1. Claim 10 recites that both laser outputs are generated by an Nd:YAG, etc. As discussed above, Kasner et al. teach a non Nd:YAG laser for providing one of the laser outputs.

Claim 19 has been cancelled because it is duplicative to claim 10. Claims 9, 12, and 13 are believed to be allowable because they depend on claim 1, which applicants believe is allowable. Applicants request, therefore, that this rejection be withdrawn.

The Examiner states that

> "[t]his application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(f) or (g) prior art under 35 U.S.C. 103(a)."

Applicants respond as follows.

The inventions of pending claims 1, 4, 5, 7, 9, 11, 13, 14, and 25-30 were conceived and reduced to practice by Bonnie Larson in April 1995; and the inventions of pending claims 2, 6, 8, 10, 12, 15, 16-18, and 20-23 were subsequently conceived and reduced to practice by Mark Owen and Jozef Van Puymbroeck. Because they depend on claim 1, claims 2, 6, 8, 10, 12, 15, 16-18, and 20-23 have Larson, Owen and Van Puymbroeck as inventors.

Thus, the inventive entities (Owen and Larson of Electro Scientific Industries, Inc., and Van Puymbroeck of Siemens, NV) for all claims pending in the present application are different from the inventive

entity or entities (Owen and O'Brien of Electro Scientific Industries, Inc.) of the priority U.S. Patent Application No. 08/276,797, now U.S. Patent No. 5,593,606. Larson and Owen were under obligation to assign patent rights to Electro Scientific Industries, Inc. at the time of their inventions. The joint development of the inventions recited in the pending claims took place in the United States at Electro Scientific Industries, Inc. under an obligation of Siemens, NV to assign all patent rights to Electro Scientific Industries, Inc., which is assignee of the priority application.

Claim 4 stands rejected under 35 U.S.C. 103(a) for being obvious over Kasner et al. as applied to claims 1-3, 9, 10, 12, 13, and 19 above, and further in view of the LaserPulse, Fall 1993 issue. The Examiner states that

> "Kasner discloses the invention substantially as claimed, but does not show the recited processing parameters.
>
> "Referring to page 6, 'UV Laser Micromachining Applications Continue to Grow' and the unnumbered page entitled '4420 Laser Micromachining System', the LaserPulse newsletter shows that it is known in the art to laser drill circuit board materials using laser pulses with temporal pulse widths shorter than 100 ns, average output powers of greater than 100 mW, and pulse repetition rates greater than 1kHz (see the specs for laser model 4575). The LaserPulse newsletter teaches that these parameters provide low thermal damage, precision depth control, and the ability to machine various materials (see page 6). It would have been obvious to one of ordinary skill in the art at the time the invention was made to use laser pulses with temporal pulse widths shorter than 100 ns, average output powers of greater than 100 mW, and pulse repetition rates greater than 1kHz as the process parameters in Kasner to provide low thermal damage and precision depth control as taught by the LaserPulse newsletter."

Applicants respond to this rejection as follows.

Claim 4 has been amended to recite that the first and second laser pulses are generated at significantly different repetition rates. The LaserPulse, Fall 93 issue, does not suggest using pulses of at least two different repetition rates to drill a blind via. The 4420 brochure states that "[the laser] solves problems associated with smaller vias, finer lines and new materials, allowing manufacturers to achieve new levels of micromachining accuracy and control." The brochure makes no further

mention of via drilling, does not mention differential ablation thresholds, does not specify parameters used to drill dielectric and conductor layers, and does not indicate that the energy density may be changed during the process of drilling a single blind via. Applicants request, therefore, that this rejection be withdrawn.

Claims 5-8, 14, 15, and 20 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Kasner as applied to claims 1-3, 9, 10, 12, 13, and 19 above, and further in view of U.S. Patent 5,073,687 to Inagawa et al. The Examiner states that

> "Kasner discloses the invention substantially as claimed, but does not show generating the first laser output so that it has a power greater than the power of the second laser output.
>
> "Referring to Figures 1-3, Inagawa shows that it is known in the art to laser drill a multi-level circuit board by generating a first laser output (R_1) of relatively high power (P_1) and applying the first output to a target area to remove a metal layer (1a), and then generating a second laser output (R_2, R_3) of relatively low power (P_2-P_5) and applying the second laser output to the target area to remove a dielectric layer (1b). The power is changed by changing the output of a pumping source (14). The process allows a circuit board to be drilled using a single laser without any adverse thermal damage to the dielectric layer (col. 5, lines 35-42). It would have been obvious to one of ordinary skill in the art at the time the invention was made to replace the dual laser system of Kasner with a single laser and to generate a first laser output with larger power and a second laser output with smaller power by changing an output of a lamp pump source to reduce the cost of the system and form a blind via with minimal thermal damage to the dielectric layer as shown by Inagawa.
>
> "Regarding claims 7, 8, 14, and 15, although Inagawa shows changing the energy incident on the target area (i.e., the energy density) by changing the power output of the laser, it would have been equally obvious to one of ordinary skill in the art at the time the invention was made to change the energy density by changing the spot size of the laser upon the target area since the examiner takes Official Notice of the equivalence of the step of changing a laser's output power and the step of changing a spot size for their use in the laser machining art and the selection of any of these known equivalents to change the energy density provided on a target surface would be within the level of ordinary skill in the art. <u>In re Fout</u>, 213 USPQ 532 (CCPA 1982). This equivalence may be shown by the equation: $E_d=(P/A)*t$, where E_d is the energy density, P is the beam power, A is the area of the beam spot on the workpiece, and t is the pulse length. The energy density may clearly be set to a desired value by changing either the power or the spot size.

"It would have been obvious to one of ordinary skill in the art at the time the invention was made to change the spot size either through using a variable focus lens or by moving the workpiece, both methods being notoriously old and well-known in the art for the purpose of adjusting a laser spot size on a workpiece, to conveniently achieve a required change in size."

Applicants respond to this rejection as follows.

Inagawa et al. are concerned with drilling through-hole vias and limiting damage to a resin layer positioned between two copper foil layers, i.e. they reduce the power of the second laser output to avoid widening or damaging the resin layer. In contradistinction to the present invention, they are not concerned with blind vias and whether or not the second laser output is below a metal ablation threshold. Inagawa et al. employ no autostop (self-limiting) feature.

In the first and second embodiments, Inagawa et al. employ only a CO_2 laser to perform the drilling. The wavelength of this laser does not fall within the wavelength range of claim 1.

In a third embodiment, Inagawa et al. employ an excimer laser (Kr:F $\lambda = 248\ \mu m$) as a first laser light source presumably to drill through the copper film adhered to a laminate plate of a printed circuit board (TLC-W-551, made by Toshiba) and a CO_2 laser (or a 1.06 μm YAG laser) presumably to drill through the resin portion. This is similar in some respects to the two wavelength system of Kasner et al. previously discussed. The repetition rate of an excimer laser beam focused to a small spot area would be too slow to use in a manufacturing process, and the wavelength of the 1.06 μm YAG laser does not fall within the claimed wavelength range. No definitive output powers are provided for any of the drilling operations.

Inagawa et al. appear to suggest the use of the excimer laser output in place of CO_2 laser output only when the CO_2 laser output would form a black carbide in the resin portion. However, they disclose the excimer limitation that the "transmittance of the laser beam deteriorates as the depth of the hole formed increases." To solve this problem, they gradually increase the pulse height. Thus, they teach away from the present invention. Increasing the pulse height as a function of depth would not self-

limit the drilling to the resin portion, but would be consistent with attempting to create a through-hole via as opposed to a blind via. Furthermore, as the Examiner notes, Inagawa et al. accomplish the method of changing the output powers by the age old method of changing the lamp currents, which is relatively slow.

In addition to the comments set forth above, applicants believe that claims 5-8, 14, 15 and 20 are allowable because they depend directly or indirectly from claim 1, which applicants believe to be allowable. Applicants request, therefore, that this rejection be withdrawn.

Claim 11 stands rejected under 35 U.S.C. 103(a) as being unpatentable over Kasner as applied to claims 1-3, 9, 10, 12, 13, and 19 above, and further in view of Soviet patent publication 1750900 to Arkhipenko et al. The Examiner states that

> "Kasner discloses the invention substantially as claimed, but does not show directing laser pulses sequentially to multiple positions defining a contiguous set of areas extending outwardly from a central portion along a path to the periphery of a spatial region.
>
> Referring to the abstract and sole Figure, Arkhipenko shows that it is known in the art to form blind vias by directing a laser beam sequentially to multiple positions defining a contiguous set of areas extending outwardly from a central portion along a path to the periphery of a spatial region ("scan [the] laser cutting beam in [a] series of concentric circles of increasing diameter"). Arkhipenko teaches that this allows laser drilling of blind vias of large diameter in printed circuit boards. It would have been obvious to one of ordinary skill in the art at the time the invention was made to direct the laser pulses of Kasner sequentially to multiple positions defining a contiguous set of areas extending outwardly from a central portion along a path to the periphery of a spatial region to enable the formation of relatively large blind vias as taught by Arkhipenko."

Applicants respond to this rejection as follows.

The abstract of Arkhipenko et al. does not disclose any laser parameters and does not teach <u>contiguous</u> small spots in the form of a spiral. Because claim 11 depends on claim 1, which applicants believe to be allowable, applicants believe claim 11 is allowable and request this rejection to be withdrawn.

Claims 16 and 17 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Kasner as applied to claims 1-3, 9, 10, 12, 13, and 19 above, and further in view of U.S. Patent 5,227,013 to Kumar. The Examiner states that

> "Kasner discloses the invention substantially as claimed, including a target comprised of two dielectric layers and at least three metal layers (Fig. 2), but does not show repeating the disclosed process to produce a stepped via as claimed.
>
> "Referring to Figure 6, Kumar shows that it is known in the art to laser drill stepped vias in printed circuit boards. It would have been obvious to one of ordinary skill in the art at the time the invention was made to merely repeat the steps of Kasner and form a stepped via to produce a desired circuit board configuration as illustrated by Kumar."

Applicants respond to this rejection as follows.

Because claims 16 and 17 depend directly or indirectly from claim 1, which applicants believe to be allowable, applicants believe claims 16 and 17 are allowable and request this rejection to be withdrawn.

Claim 18 stands rejected under 35 U.S.C. 103(a) as being unpatentable over Kasner as applied to claims 1-3, 9, 10, 12, 13, and 19 above, and further in view of Harris et al., "MCM Micromachining: Nd:YAG UV Laser Process is a New Option." The Examiner states that

> "Kasner discloses the invention substantially as claimed, but does not disclose producing non-circular vias.
>
> "Referring to the Figure labeled "No Masks Needed," Harris shows that it is known in the art to laser drill non-circular vias. It would have been obvious to one of ordinary skill in the art at the time the invention was made to use Kasner's process to form a non-circular via to produce a desired circuit board configuration as illustrated by Harris.

Applicants respond to this rejection as follows.

Because claim 18 depends directly from claim 1, which applicants believe to be allowable, applicants believe claim 18 is allowable and request this rejection to be withdrawn.

The Examiner states that

> "[t]he prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Davis, Leary-Renick, Arai, Wai,

Owen, Bachmann, and Martyniuk show laser drilling blind vias. Takahashi shows changing energy density by changing a spot size."

Applicants note that Bachmann is from Siemens, which has sold the production line based on the Bachmann invention, and has invested heavily in ESI machines that employ the present invention.

Claims 21-30 have been added. Claims 21-29 depend directly or indirectly from claim 1. In particular, claim 23 recites a nonexcimer laser; claim 25 recites that the laser outputs have different repetition rates; and claim 28 recites that the first laser output has a repetition rate that is greater than 200 Hz and the second laser output has a repetition rate that is greater than the first. Since these claims depend from claim 1, they should be allowable if claim 1 is allowable.

Claim 30 is a product by process claim.

Applicants believe that their application is in condition for allowance and respectfully request the same.

Respectfully submitted,

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